Williams (F. H.)

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OF THE

ADAPTATION OF THE X-RAYS

TO

MEDICAL PRACTICE

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BOSTON

[*Reprinted from Medical and Surgical Reports of the Boston City Hospital, January, 1897.*]

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A STUDY OF THE ADAPTATION OF THE X-RAYS TO MEDICAL PRACTICE AND SOME OF THEIR USES.

By Francis H. Williams, M.D.

In the winter of 1896, not long after the announcement in America of Professor Roentgen's discovery of the X-rays, I was impressed with their possibilities for usefulness in the practice of medicine, and as soon as I had gained some familiarity with the physics of the subject I began to examine my patients by their means, and have done so constantly ever since. The number I have thus far examined amounts now to more than two hundred and fifty, and the more extended my experience has become in making these examinations, the more valuable have I found the rays in diagnosis in suitable cases.

During the progress of this study I have from time to time reported my results at medical meetings [1] or by published articles,[2] but only in outline, and I shall now endeavor to present more fully, at least a part of my work at the Boston City Hospital. The use of the X-rays in medicine was so new that apparatus and methods had to be devised before patients could be examined satisfactorily, and as members of the profession from various parts of the country have been interested in seeing my methods, it will perhaps be useful to describe for others some of the apparatus used, before taking up the medical side of the subject.

Of the various forms of apparatus employed to excite the Crookes tube I have found the static machines, although

[1] Meeting of the Suffolk District Medical Society, April, 1896.

Meeting of the American Association of Physicians, April 30, 1896.

Meetings of the Boston Society for Medical Improvement, and of Medical Society of the Boston City Hospital, October and November, 1896.

[2] "Proceedings of the American Association of Physicians," 1896. "Boston Medical and Surgical Journal," Oct. 1, 1896.

at a disadvantage in moist air, the most satisfactory, and of these prefer that known as the Wimshurst. The one I have principally used was designed by Mr. C. L. Norton and Mr. R. R. Lawrence, of the Massachusetts Institute of Technology (see Fig. 1), and has twelve glass plates, 26 inches in diameter, which are run at about 200 revolutions per minute, and is boxed in order to keep out the dampness. I have ordinarily used it without condensers in making examinations with the fluorescope, but in taking radiographs

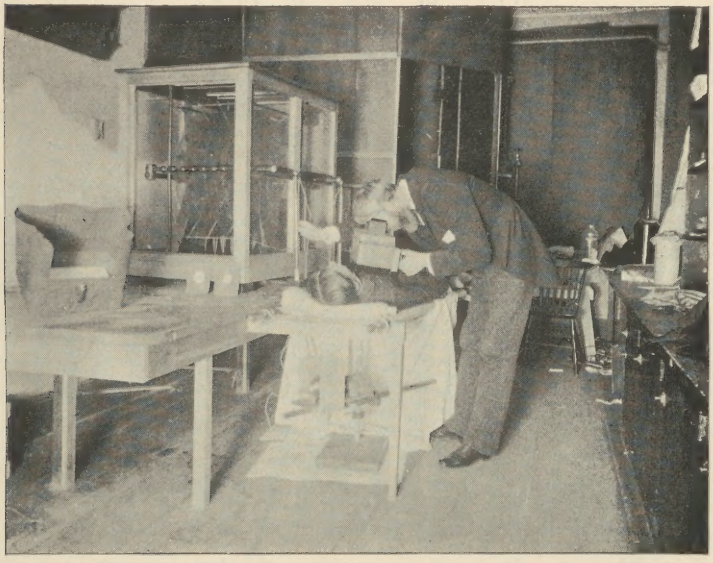

FIG. 1.—Static machine and stretcher, with tube holder below; large fluorescope at left of picture. This cut shows method of examining a patient.

condensers are an advantage. It may be of interest to state here that I found the surface of the glass plates was less susceptible to dampness when a few drops of castor-oil were added to the thin shellac with which they were coated. Vulcanite plates may be used instead of glass plates, but they do not seem to be as good electrically, although, of course, they are less likely to be broken; still, with ordinary care, there is not much danger to glass plates while handling the machine, and those of 26 inches in diameter I have run, in order to test them, at 900 revolutions a minute without breaking them, even though not carefully centred,

while those of a smaller size, if carefully balanced, may be run at a much higher speed. Attachments to the Crookes tube for lowering the vacuum are not necessary when using this machine, as the vacuum is only slowly raised.

The Crookes tube does not seem to require a large amount of electricity for its successful use. The prevention of leakage — and this leakage is very great in moist air — is the practical difficulty to be overcome. To this end, all parts of the machine should be carefully insulated, and leakage from the conducting wires and connections reduced as much as possible. The tube should be exhausted to the degree of pressure suitable to the apparatus used, a large static machine requiring a tube with a high degree of exhaustion. The resistance of the tube increases after it has been used for some hours, but this resistance may be reduced by heating the tube over a flame while turning it in the hand. This does not require to be done often. There are certain limits in the vacuum between which the X-rays are given off: if the vacuum is too low there are no rays; if too high the resistance of the tube is so great that it cannot be overcome and no fluorescence is produced on the screen. The best results seem to be attained when the vacuum is as high as the tube can be made to work successfully. The following suggestions from the experience of Mr. G. A. Frei are sometimes serviceable: If the vacuum is a little too low it may be made higher by running the tube with a closed spark-gap; if too high it may be lowered by running the tube with a closed spark-gap and with the current reversed. If there is not time to lower it in this manner the difficulty may sometimes be overcome for the moment by grounding the anode.

To do the best work, good Crookes tubes are necessary, and an abundant supply of suitable electricity, more or less of which can be used as the conditions of the moment require.

Next in importance to a good machine for exciting the X-rays and a good Crookes tube comes the fluorescope. Fluorescopes with screens made of tungstate of calcium have generally one great disadvantage; namely, the screen remains bright, and the image of the object persists sometimes for

several minutes after the fluorescope is taken away from the tube; but from the tungstate of calcium screen, which is the result of the patient and laborious investigation of Mr. T. B. Kinraide, of Jamaica Plain, Boston, Mass., the image disappears as soon as the fluorescope is removed from the tube. I use three sizes: one 3 by 4 inches, one 7 by 9 inches, and the third 11 by 14 inches.

Being now supplied with satisfactory apparatus, how can we use it to obtain the best results, and at the same time render the patient most comfortable during the examination?

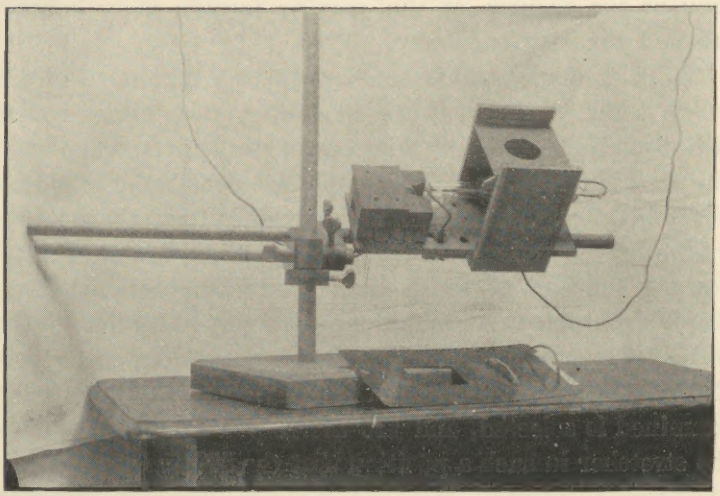

FIG. 2. — Holder for Crookes tube; metal plate with rectangular opening lying on base of holder.

The room in which the examination takes place should be darkened, and, for further facilitating the end we have in view, I have devised the following appliances: First, the use of a canvas stretcher (see Fig. 1), which is placed when needed on supports connected with the table on which the static machine stands, and which may be drawn out or pushed in at pleasure. The patient rests easily on this stretcher, and may turn from side to side if required, and all portions of the body can thus be readily examined.

Second, an adjustable stand for holding the Crookes tube (see Fig. 2), the arm of which may be raised or lowered, shortened or lengthened, as desired. This may be placed

under the stretcher, and as the X-rays penetrate the canvas as easily as they do the clothing, the patient is, as it were, suspended in the air over the tube, and all portions of the body are accessible. While examining the patient through the fluorescope held in one hand, the other is free to change the intensity of the light, which is readily done by varying slightly the length of the spark-gap. It is important to have sufficient light, but it is equally important not to have too much light. It is also sometimes advantageous during an examination with the fluorescope to move the Crookes tube from side to side, and by thus changing the position of the shadow of the part or foreign body more is learned than by one view.

Third, a device which enables us to overcome the difficulty which we sometimes encounter, of getting a sharp definition and excluding unnecessary rays even when using the best fluorescope. This appliance consists of a piece of sheet metal (*e.g.*, brass) six inches wide by twelve inches long, and thick enough to prevent the passage of the X-rays, toward one end of which is cut a rectangular opening — this is preferable to a circular one — about two by three inches being a convenient size. After taking a general survey with the fluorescope, the part of the body that is to be carefully examined is selected, and the metal plate held close under the stretcher in such a position that the X-rays coming from the Crookes tube fall directly through the opening, while the surrounding area is shielded by the metal. The fingers should be protected from the rays while holding the plate, and to accomplish this object leather straps are fastened on to the plate, so that the fingers may be inserted under them on the upper side; the plate may be moved about and any special part examined. A diaphragm may be used near the Crookes tube, instead of the plate, made of sheet metal with a circular opening from about one to two inches in diameter, which may be slid into the grooves of the wooden pieces on each side of the tube. When in a groove near the tube the cone of rays is broad, when farther away it is narrower.

Fourth, a pencil for tracing the outlines of a given organ or object during the examination of the patient with the fluorescope. This pencil is made of metal, with a crayon

point suitable for marking the skin, and along one side is a strip of lead wire which is held in place by means of sticking-plaster wound around the pencil. Were it not for this lead the X-rays would pass through the crayon so that it would not be visible, but by its means a dark shadow is cast, and one can see, as it were, the end of the crayon.

The radiograph and fluorescope are both useful in practice. In taking the former it is most convenient to place the Crookes tube above the portion of the body of which a picture is desired, and the best direction of the part with regard to the tube in other respects may be frequently learned by previously examining the patient with the fluorescope. The nearer the part to the photographic plate, and the greater the distance of the tube, the sharper the picture. As in practice it is requisite to spare the time of the practitioner as much as possible, photographic plates wrapped in dark paper and enclosed in envelopes to protect them from the light are convenient, because, after being exposed, they may be sent, without opening the envelope, to the photographer to be developed. If it is desirable to have a picture within a few minutes, bromide paper enclosed in dark envelopes may be used, and developed directly. This is, I believe, the readiest way of obtaining a permanent record by means of the X-rays. If other copies are desired, the bromide paper may be coated with oil or paraffine, and prints may be made from it as from a glass negative. If two or three pieces of bromide paper are placed in the same envelope with a glass photographic plate, which, as already stated, is first wrapped in dark paper, the advantages of both methods are combined. A fluorescent screen is sometimes placed against the photographic plate in order to shorten the time of exposure. The objection to this method is that the radiographs are somewhat mottled and the picture loses in clearness. The following method is useful and satisfactory in taking radiographs. The sensitive side of a sheet of bromide paper is placed upon a thick screen of tungstate of calcium made of uniformly fine crystals and with a perfectly smooth surface. The rays pass readily through the paper, act first upon its coating, and

then cause the tungstate of calcium to fluoresce. This fluorescent light also acts photographically upon the bromide paper, and the total effect of the action of the rays is very much increased.

The radiograph gives the permanent record, and makes finer distinctions possible, but, in the nature of things, affords only one view of a given organ or bone; whereas the fluoroscope enables us in a moment to see these from different points of view, and we can thus get a better idea of the conditions present in a short space of time. The fluoroscope is likewise peculiarly applicable to moving organs, such as the heart and lungs.

An examination with the fluoroscope may give an erroneous idea of the size and position of a given organ unless the relation of the position of the Crookes tube to the body is understood. By position I include distance and direction. This must also be borne in mind when taking a radiograph. In an examination of the heart, for instance, when the Crookes tube is about six inches behind the back of the patient and the screen of the fluoroscope is directly over the chest, it is obvious that the shadow of the heart will be much larger than the heart itself. To gain an exact knowledge of the size of the heart the Crookes tube should be two feet or more from the screen of the fluoroscope, which should be held close to the body.

Let me describe the method pursued in one of the simplest practical uses of the X-rays; namely, that of locating a bullet, whether in the head, body, or extremities. If unable to walk, the patient is brought in on a stretcher, which is placed directly on the supports attached to the static machine table (all the hospital stretchers are of the same size and fit the grooves in the supports), and the Crookes tube is placed underneath. If the physician has just come into the dark room from bright daylight, he must wait until his eyes accustom themselves to the darkness; the machine is then started, and the spark-gap adjusted to the length most suitable to the condition of the tube, this length being determined by examining the patient through the fluoroscope.

Everything being now in readiness, the fluoroscope is

placed directly on the thigh (let us suppose the bullet is there), and the examination is begun. After looking a moment the spark-gap may be changed a little in order to increase or diminish the light, as by means of this variation more can be seen, certain things showing better in a bright light and others in a less brilliant one. With a bullet it is generally well to use a considerable amount of light. After the fluorescope has been moved about a little, the shadow of the bullet is found, and the spark-gap may again be changed in order to get as clear a shadow as possible. The physician, while still looking through the fluorescope, then makes with the pencil already described a mark over the place where the bullet seems to be, and directly under the fluorescope; he then makes a corresponding mark on the side of the thigh nearest the Crookes tube, over the shadow of the bullet, and draws 1 and 1 by the side of each of these two marks. Then, while still looking through the fluorescope, the Crookes tube should be moved horizontally a few inches to and fro in order to learn how deeply the bullet is imbedded, for if the shadow of the bullet moves considerably in the fluorescope the bullet is some distance away. If it moves very little it must be near the fluorescope and the surface of the skin. If far from the surface its shadow will, of course, be ill-defined; if near, it will be very sharply defined. Next, the patient should be turned so as to allow the physician to look through the thigh in a direction about at right angles to that first taken, and, as before, a mark should be made with the pencil over the place where the bullet seems to be, both when the point of the pencil is held directly under the fluorescope and on the side of the thigh nearest the Crookes tube. These points should be marked 2 and 2, and the bullet will be found at the point where the line drawn from 1 to 1 intersects that drawn from 2 to 2. I have used this method for locating bullets in different parts of the extremities, and in the neck, thorax, back, and abdomen, and usually the situation of the bullet is readily determined by this means. The first bullet I located in this way was in April, 1896.

Let us now consider the principles upon which the use of the X-rays depends. These rays are probably, so far as our

present knowledge goes, ether waves, but shorter than the waves of light, perhaps $\frac{1}{10}$ to $\frac{1}{15}$ as long. Two properties of these rays interest us especially, and upon them depends their usefulness in medicine: First, their power of exciting fluorescence in certain substances. When the X-rays strike tungstate of calcium in a dark room it is seen to fluoresce, and the greater the number of rays which come into contact with it the greater the fluorescence. Second, the difference in their ability to penetrate different substances. It is more difficult for these rays to penetrate bone than muscle, for instance; hence more are intercepted in their passage through the former than the latter, with the result that a darker band is seen upon the bright screen in the one case than in the other. The picture we get in the fluoroscope and the impression made upon the photographic plate depend, then, upon the greater or less resistance which the various parts of the body offer to the Roentgen rays. Let us therefore consider briefly the principal causes of this difference in permeability. First, bulk: a thin layer of a given substance will be more readily penetrated by the rays than a thicker one; second, chemical composition. The first needs no comment; but the second deserves attention, as a clear appreciation of the possibilities and limitations of the X-rays in distinguishing between healthy and diseased parts is based largely upon a knowledge of the chemical composition of these parts. This knowledge leads us to avoid mistakes and disappointments on the clinical side which would not be experienced did physicians and surgeons appreciate the relation of the X-rays to chemical composition, and points out certain ways in which these rays are capable of rendering aid.

The following experiment with calculi illustrates in a striking manner how important to us is a knowledge of the chemical composition in our use of the Roentgen rays in medicine. Before attempting to detect any form of calculi in the body, I first placed several different kinds over a photographic plate, which was enclosed in dark paper to shield it from the light, and exposed them for a few minutes to the X-rays. The rays penetrated the calculi made up of uric acid, of cholesterine and biliary salts, very readily, but were

obstructed by calculi containing oxalate of calcium in considerable proportion, phosphate of calcium, or other inorganic constituents. Further study showed that organic substances are quite as readily penetrated by the X-rays as the soft tissues of the body, and therefore it is obvious that any attempt to detect in the body calculi made up of organic compounds would, so far as our knowledge now goes, be futile, whereas those of inorganic origin might be detected.

If diagnosis by some other means than the X-rays shows that there is a calculus in the bladder, for instance, which cannot be demonstrated by a good radiograph taken by

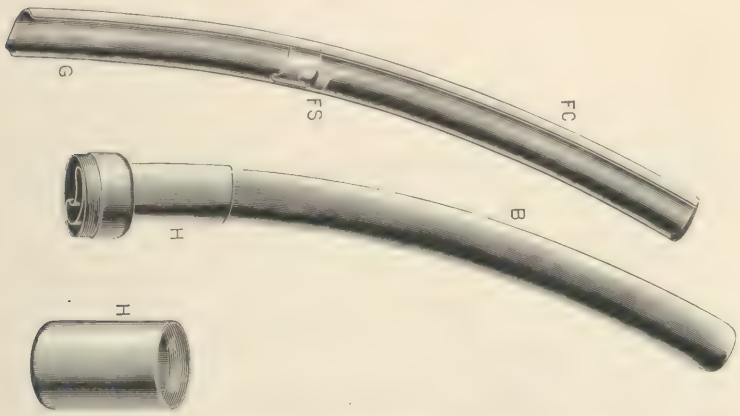

FIG. 3. — Instrument for radiographing a calculus in bladder.

means of an instrument described below, we know it is made up of uric acid or some substance composed chiefly of organic constituents. Calculi may occur made up of substances some of which are, and some of which are not, permeable by the X-rays. The instrument just referred to was devised by Dr. William H. Rollins, of Boston, and consists of an aluminum tube 9 inches long and 1 inch wide, a cross section of which bears some resemblance to a crescent, one-half of its outline being in a general way parallel to the other half. The tube is closed with a solid piece of metal at one end, and to the other is fitted a handle which screws on (see H and H, Fig. 3). FC is a thin piece of metal with grooved edges which holds several pieces of photographic film or pieces of bromide paper which should be about as wide as the tube

and about half as long. To put the films in place the sliding piece FS is removed from FC, the films slid into the grooves and pushed to the end as far as they can go, after which the piece FS is put back to hold the films in place. The whole is then pushed inside of HB and the round handle H screwed on; this must be done in a dark room. The instrument carrying the films, with the convex side up, is then inserted into the rectum of the patient, who is placed on his back, and the instrument is held in such a position that the films are brought just below the bladder. The rays from the Crookes tube, which is placed over the bladder and some inches from the abdominal wall, penetrate the tissues and the aluminum wall of the tube and act upon the film. After an exposure of a few minutes the instrument is withdrawn and the films taken out in a dark room and developed like any photographic plate. In the two cases in which I have used this instrument nothing was found on the films; the calculi were removed and proved on analysis to be made up of uric acid.

Fig. 4 is taken from a radiograph of the various calculi already referred to, which were lent to me by Dr. William F. Whitney, from the Harvard Medical School, and at his suggestion I added to the plate a dry bone, an incinerated bone, and a decalcified bone. The removal of the organic matter from the incinerated bone made little difference in the penetration of the rays, whereas the removal of inorganic matter (mineral salts) in the decalcified bone allowed the rays to pass readily.

In order to gain some conception of the susceptibility of the various constituents of the body to the X-rays, I made several radiographs of a considerable variety of substances, and one of them I have had reproduced here. The conditions of this experiment, the result of which is shown in Fig. 5, were as follows: Equal bulks of substances which represented in a general way the chemical constituents of the body were placed in small pasteboard boxes of the same size, namely, 15mm. in depth, 38mm. in length, and 25mm. in width, those containing liquids being first coated inside with shellac, and the weights and contents being noted on each box. The boxes were then placed on a photographic

ERRATUM.

Page 12, 12th line from top of page, for "inches" read "distance."

plate enclosed in dark paper, and exposed for about two minutes to the action of the rays at a distance of two feet.

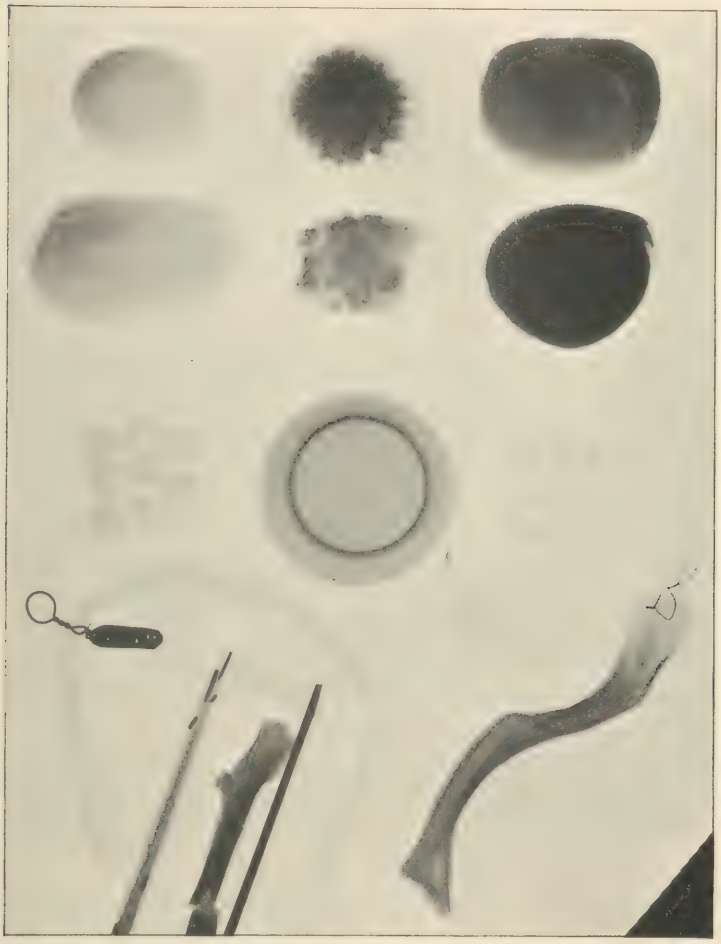

FIG. 4. — The two upper rows of objects in this radiograph are calculi. The two calculi on the left are composed of uric acid and urates; those on the right of phosphates; and the two in the middle of oxalate of calcium and uric acid, the upper one of these last two having an outside coating of urates. In the centre of the picture is a round aluminum cup, containing water, one inch in depth, and on either side of this cup is a group of gall stones, and to the right and below the cup a single large gall stone is seen indistinctly. In the left-hand lower corner is a decalcified bone, bent into the shape of ∩, with a lead tag attached by a copper wire. The decalcified bone surrounds an incinerated bone, which is lying on a piece of cotton wool in a wooden box with a glass side. In the right-hand lower corner is a dry bone; in the extreme right-hand corner is a triangular piece of lead. The picture is reduced to one-third of its original size.

The result here also showed that the organic substances are more readily penetrated than the inorganic, and that some

of these latter, notably the salts containing considerable calcium or chlorine, for example, most obstructed the passage of the rays. In many radiographs which I have taken of patients, different tissues may be recognized, owing in part to variation in chemical composition; one sees, for

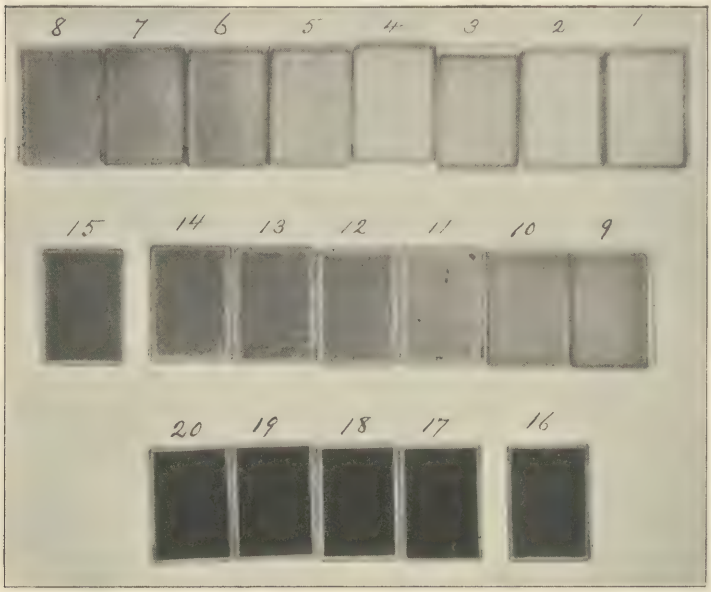

FIG. 5.—Radiograph of equal bulks of various substances which represent the constituents of the body in a general way.

	Weight.		Weight.
1. Carbonate of magnesium,	1.6 grammes.	5. Gelatin	4. grammes.
2. Stearic acid	3.8 "	6. Dried egg albumen . . .	6.4 "
3. Oleic acid	3.5 "	7. Carbonate of sodium . .	5.9 "
4. Palmitic acid	4.4 "	8. Milk sugar	11.7 "
9. Glycerine	4. grammes.	13. Phosphate of calcium . .	2.6 grammes.
10. Water	14. "	14. Sulphate of sodium . .	10.8 "
11. Oxalic acid	12.2 "	15. Magnesium ammonium phosphate	12.5 "
12. Phosphate of sodium . .	10.6 "		
16. Chloride of sodium . .	8.5 grammes.	19. Carbonate of calcium . .	15.3 grammes.
17. Sulphur	13.9 "	20. Fluoride of calcium . .	11.7 "
18. Chloride of potassium .	10.1 "		

example, the skin, a layer of adipose tissue, muscles, normal bone, and chemical changes in bones due to disease.

The radiographs[1] of the teeth first taken by Dr. Rollins show beautifully the bone of the jaw, the enamel of the tooth, the dentine, and the tooth canal. This is probably largely a question of chemical composition.

[1] "Boston Medical and Surgical Journal," Vol. 135, page 90, 1896.

Let us see what further light may be had on this subject from a chemical standpoint. It is known that the chemical elements vary, generally speaking, in the ease with which they are permeable by the rays according to their atomic weights. These weights range from 1 to 238.5. We do not find all these elements in the body, but only those, in any considerable amount, which are given with their atomic weights in Table I.

TABLE I.

Element.	Atomic weight.
Hydrogen	1.
Carbon	12.
Nitrogen	14.
Oxygen	16.
Fluorine	19.
Sodium	23.
Magnesium	24.
Phosphorus	31.
Sulphur	32.
Chlorine	35.5
Potassium	39.
Calcium	40.
Iron (to small amount only)	55.9

Further, about two-thirds of the body by weight is water (molecular weight, 18), and the soft tissues are largely made up of it.

	Water.
Ligaments contain about	77%
The voluntary muscles, about	75%
(They contain nearly one-half the water of the body.)	
Cartilage	55%
Bones	13%
Teeth	10%
Epidermis	3%

The various fluids formed in the body in health or disease, such as the blood, ascitic and pleuritic fluid, the urine, pus, fluid from hydrocele, etc., are made up chiefly of water, and are found to offer about the same resistance to the pas-

sage of the rays as does water when compared under the fluorescope. That is, the difference in the amount of light as seen in the fluorescope which passed through each of these fluids when placed respectively in a vulcanite cup, compared with an equal amount of water in a vulcanite cup, was not marked. From such observations and from our knowledge of the composition of the constituents of the body we can infer that its soft tissues, except adipose tissue, will present about the same resistance to the passage of the rays as an equal bulk of water, whereas the denser tissues which differ from water in their chemical composition and contain elements of a higher atomic weight than oxygen, the chief weight of water, will present a greater obstacle than water to the passage of the rays. It will occur to those familiar with the composition of the various tissues of the body that in some, muscle, for example, the organic constituents made up of carbon, hydrogen, and nitrogen would tend to make it more penetrable than water, whereas any small amount of mineral matter would diminish its permeability: that is, the average of the soft tissues would not be far from water.

There is one other point which must not be overlooked in this connection, and that is the difference in resistance which air and water offer to the passage of the X-rays. The rays pass through air much more readily than through water, and as air makes up a certain bulk of the body, a large part of the chest is filled with it, while water enters into the composition of all parts of the body and forms the chief constituent of the soft parts, it is readily seen of how much importance is this difference in permeability of air and water by the rays, on account of the great contrast which is thereby afforded in health between the lungs and their adjacent tissues or organs. Further, as will be shown later, one of the best opportunities for the advantageous application of the X-rays is obtained from the contrast of the normal lung tissue with that offered by pathological conditions which occur in the thorax, involving chiefly increase in density in the lungs or in the space usually occupied by them.

To use the Roentgen rays successfully in practice, it is first essential that the physician become familiar with the appearances in the fluorescope which present themselves in

health. This applies particularly to the thorax, and the picture of this part of the body when seen in the screen of a large fluorescope presents so much that it should be studied systematically. The trunk appears lighter above than below the diaphragm, and the rise and fall of this muscle, which appears dark in the fluorescope, are distinctly seen. The chest is divided vertically by an ill-defined dark band, which includes the backbone, on each side of which the lungs, forming the brightest part of the picture, are crossed by the darker ribs. The pulsating heart is seen, especially the dark ventricles, and, under favorable conditions, the lighter right auricle, and on the left side above the ventricles the pulmonary artery is made out. A small portion of one side of the arch of the aorta may be observed in the first intercostal space to the left of the sternum. After this general view has been taken, the outline of the lungs should be noted during full inspiration and expiration, and the excursion made by the diaphragm during quiet breathing and during full inspiration and expiration. The lungs usually appear brighter during deep inspiration: in young persons brighter than in older persons, as the tissues of the former are more easily penetrated by the rays. In the thin, the lungs appear lighter than in the heavy, because the outlines are dulled, as it were, by a thicker layer of tissues, which contain much water. It has seemed to me that the right apex is normally darker than the left apex. The normal brightness of the lungs and the normal outlines of the clavicles and ribs should be observed, for as we note different degrees of pallor by reference to our standard of color in health, in the same way is it necessary to know the normal amount of light which should penetrate any given part in order to recognize variations from the normal. The eye must be trained in the use of the X-rays as is the ear for auscultation and percussion. In Fig. 6 the two upper lines on either side of the chest indicate the position of the top of the diaphragm during expiration and inspiration respectively in quiet breathing; the lower on either side, the top of the diaphragm in full inspiration; the line of complete expiration nearly coincides with that of expiration in quiet breathing. The spot below the nipple is where the apex beat was felt.

The Crookes tube was directly under the junction of the ensiform cartilage with the sternum.

In six men with healthy lungs the diaphragm moved on an average two and three-fourths inches on the right side and two and one-half inches on the left side. In eighteen patients with tuberculous lungs the average excursion of the diaphragm was one and one-fourth inches. In health the diaphragm is less sharply defined in expiration than in inspiration.

The heart in some healthy persons moves in deep inspi-

FIG. 6. — Chest of man, showing diaphragm lines in quiet breathing and deep inspiration, and part of the outline of the heart.

ration downwards and toward the median line about one-half an inch.

To test the possibilities of an examination with the fluoroscope in certain conditions of the lungs, as when congestion or more or less œdema or pleurisy was present, I tried one or two simple experiments. On full inspiration in healthy patients I found the pulmonary area lighter than in other stages of respiration, and the ribs stood out in greater contrast, thus showing that there must be less blood in the lung during the former period, and that if any part of the lung is much congested, or if œdema is present, it would naturally appear darker than the normal lung; also, when I held a small pasteboard box, about one-half inch

deep and full of water, over one side of the thorax of a well-developed and muscular man with a large chest, I could see its shadow in the fluorescope during about full inspiration, but not at other times.

In order to get further suggestions in regard to the possibilities of the X-ray examinations in diseases of the lungs, I took a number of radiographs of healthy and diseased lungs just after death. As a specimen of the latter, see Fig. 7, which shows the lungs of a patient who died of pneumonia. The darker was more affected by the process than the lighter; the lightest portion is healthy. These lungs were kindly sent to me for a few moments by Prof. W. T. Councilman. The autopsy of one of my patients showed he had perfectly healthy lungs. I had examined the chest of this man with the fluorescope two days before his death, and found his lungs perfectly clear and the outlines well defined. The outlines also of the front and back portion of the ribs, forming a lattice work as shown in the fluorescope, were well seen.

We shall see later that in certain diseases parts or the whole of one or both lungs appear darker or lighter than in health, and that their volume may be greater or less than in health. The respiratory excursion of the diaphragm may vary from the normal on either or both sides of the chest, in position; that is, it may be higher or lower in the body, and in amplitude. In making examinations, changes in the amount of light seen in the fluorescope should be carefully observed; for example, whether or not one lung is darker than the other. In pathological conditions the indications of change in density, shown usually by diminished brightness, may be estimated by comparing the two sides and observing whether the outlines of the organs, and whether the ribs and clavicles, are more clearly seen on one side than the other. When both sides are diseased the opportunity for direct comparison with the normal is lost, and one is obliged to depend upon the recollection of the normal in an individual of the same build.

The position, excursion, and curve of the diaphragm should also be carefully noted. If these are normal there is little probability that the lungs are diseased; but in tuber-

culosis or pneumonia, when the lung, which should be well filled with air, is made denser by some pathological process,

FIG. 7. — Lungs from a patient who had died of pneumonia. The darker lung has been more affected by the pneumonic process than the lighter.

or, if the elasticity of the lung is diminished, the excursion made by the diaphragm will be less than in health, and will be reduced from the lower side: that is, the diaphragm

would not reach so low a point in the chest. In emphysema, on the contrary, although the excursion of the diaphragm is also less than in health, it goes further down into the chest than when the conditions are normal. When there is fluid in the pleural cavity the outline of the diaphragm is obscured.

I have thus far considered some general principles and described a few simple experiments which have a bearing upon the practical applications of the X-rays to medical practice, and have indicated some of the inferences which may be drawn from them, and will now consider the clinical side of the subject.

By the courtesy of my colleagues of the hospital staff, under whose care most of these patients were, I give a brief outline of the physical examination of a number of them, and have added what I found by the X-ray examination. We will consider first cases of pulmonary tuberculosis. Most of these patients presented well-marked signs of the disease when they entered the hospital, but in private practice the proportion of patients who are seen in the early stages, when there is greater opportunity for successful treatment, is larger, and therefore the earlier diagnosis which the fluorescope assists us to make would be of special value in these cases.

In tuberculosis of the lungs the fluorescope indicates disease in the following ways:

A diminution in the volume of the diseased lung is shown by the position and movement of the diaphragm, and increase in density by a diminution in the normal brightness, the degree and extent varying in accordance with the increase in and extent of the density. The lung may become so dense that no more rays pass through it than through the liver. The brightness or light in the lungs indicates the amount of air present in them.

The following cases of tuberculosis taken from those I have examined, more than fifty in number, illustrate several points: Correspondence between the physical signs and the X-ray examination in a considerable number of cases; more extensive disease than was shown by the physical examination in certain cases; an earlier increase in density in the

lungs than was detected by the physical examination in still other cases; in one of these no signs in the lungs were detected prior to that found by the fluorescope, while in some, although one lung was ascertained by the physical examination to be seriously involved, its companion was not suspected until the X-ray examination revealed its increased density; fourth, three cases suggest that increase in density was not present where the physical signs intimated it. In a few cases the physical signs gave more information than the X-ray examination, but these were cases that were examined before I had had much experience in the use of the fluorescope. It will be noticed that in some of these cases nothing essential was learned by the X-ray examination that the physical examination had not already shown, but it should be said that in the beginning of my study it was instructive to examine any tuberculous patient, for if the correspondence between the physical signs and the X-ray examination had proved not to be evident in well-marked cases, it would have been useless to pursue the subject farther. At first, in order to make the X-ray examinations without bias, I examined the patients with the fluorescope before knowing anything of the physical examination. My object was to seek for any method that would assist in making a diagnosis as early as possible, and the X-ray examination is of service, to recapitulate somewhat, if it reveals to us changes in the lungs earlier than we have been able to learn of them in other ways; and if it will assist us to ascertain better than heretofore the extent to which the lungs are involved, whether to a greater or a less amount; in cases where the physical examination seems to show that the lungs are denser than normal, but the fluorescope shows that they are clear, we may be enabled by the aid of the X-rays to make a more favorable or more guarded diagnosis. Obviously, in a well-marked stage of tuberculosis of one or both lungs, it is useless to make an X-ray examination for purposes of diagnosis, although in these cases it is serviceable in estimating the extent of the disease. When no signs, or only doubtful ones, are found by auscultation and percussion, the X-ray examination should be made, and in such cases

we usually have the opportunity of comparing a diseased with a healthy lung. It should be borne in mind that in the use of the fluorescope we are not wholly dependent on the recognition of increase in density to suspect disease in a lung, but have also a way of judging whether its volume and elasticity are normal or not by observing carefully in the fluorescope the movement of the diaphragm during respirations.

Some of these tuberculous patients in whom the disease was advanced died while in the hospital, but as there were no autopsies, it has not been possible to know how far what was seen in life under the fluorescope corresponded to the appearances after death.

In the following 18 cases the examination with the fluorescope showed that the disease was more extensive than the physical examination indicated; it also showed in cases 1, 2, 3, 4, 5, 6, an earlier increase in density than was indicated by the physical examination. In cases 2, 3, 4, 5, 6, the physical examination indicated disease in one lung, but did not show that the other was likewise involved, as did the examination with the fluorescope.

In case 7 the fluorescope showed increase in density at the left apex when it was doubtful by auscultation and percussion.

In case 17 appearances in the fluorescope suggested a cavity in the upper part of the lung; the physical signs noted, after the examination with the fluorescope, corresponded with this observation.

Examination with fluorescope showed increase in density in the first six cases earlier than the physical examination:

1. M. M., 23 years. Tuberculosis. Family history tubercular. History of haemoptysis, physical examination negative except a few clicks at the junction of second rib and sternum on right, and at left apex behind.

Examination with fluorescope: Darker over three-fourths of right lung, and also at left apex to second rib; on the right side the thorax was darker than normal nearly to line of liver; on deep inspiration the lower portion of the right lung was clearer than the part above.

[Three weeks after X-ray examination there was found slight dulness at left apex back and front, with harsh respiration and increased voice-sounds.]

Examination with fluorescope showed in the following five cases that not one, but both lungs were involved:

2. B. J., 27 years. Tuberculosis. Tubercular family history. Haemoptysis. During past month dyspnoea, weakness, night-sweats, little cough. Marked signs of tuberculosis below second rib over whole left side; right lung negative.

Examination with fluorescope: Whole of left lung much darker than normal, no heart outline, no diaphragm outline seen on left side. Right apex darker than normal to lower border of second rib.

3. L. C., 44 years. Tuberculosis. Dulness, with râles over left side down to third rib in front and middle of scapula behind.

Examination with fluorescope: Somewhat darker at both apices down to lower border of third rib, and to some extent below; excursion of diaphragm much less than normal, ½ inch on right side, ¾ inch on left.

4. H. A., 20 years. Tuberculosis(?) Duration, four weeks; family history not tubercular. Medium dry râles at left apex, with slight dulness; right apex normal.

Examination with fluorescope: Left lung extending to level of the fourth rib very dark; there is also some involvement of right apex. The maximum respiratory movement of the diaphragm on the left side is only ¾ inch; on the right side 1 inch only. This is less than half the normal.

[Later tubercle bacilli were found.]

5. R. J. M., 44 years. Anorexia; loss of flesh; percussion, dulness at right apex, front and back, to third space and middle of scapula; expiration prolonged, râles; increased voice-sounds; left side normal.

Examination with fluorescope: Right lung darker to fifth rib; left lung darker than normal as far as second rib.

[Tubercle bacilli found later.]

6. S. S., 35 years. Tuberculosis. Mitral stenosis. A few scattered sonorous râles. In left back from 1 inch below angle of scapula are many fine and medium moist râles. Two negative examinations for tubercle bacilli.

Examination with fluorescope: Right lung to level of nipple darker than lower portion of right lung; whole of right lung denser than left lung. Left lung at apex (to second rib) rather darker than normal; lower part of left lung the clearest part of the chest.

7. R. M., 24 years. Pleurisy +. Signs in right apex and friction rub at right base, a question of left apex; slight haemoptysis.

Examination with fluorescope: Both apices darker to third rib on right side, not so far on left. [Five weeks later dulness in both apices, more in the right apex.]

8. F. J., 26 years. Tuberculosis. Marked dulness of right apex above clavicle; less dull to third rib; increased voice-sounds; respiration slightly harsh; expiration prolonged; moist râles at apex.

Examination with fluorescope: Whole of right side darker than left side, especially upper half of right lung: ribs in upper half of right chest seen very indistinctly; ribs seen very clearly on left side; outline of diaphragm distinct on left side during expiration; outline of diaphragm not distinct on right side; in fact, not well made out.

9. L. J., 23 years. Tuberculosis(?) Family history tubercular. Haemoptysis. Lost fifteen pounds; dulness under right clavicle, with fine moist râles after cough; practically no other abnormal signs.

Fluorescope: Increased darkness on right side to lower border of third rib; also on left side darker than normal.

10. T. M., 34 years. Tuberculosis. Night-sweats and loss of flesh; fair resonance over both fronts; over upper third of right front respiration is rather harsh; on the left above the clavicle and down to fifth rib are numerous coarse, moist râles; left back: resonance somewhat deficient throughout.

Examination with fluorescope: Both apices darker than normal to upper border of third rib on right, and to upper border of fifth rib on left side; outlines of ribs at apices not defined; left border of heart not defined on account of increased density of lung.

11. M. W., 17 years. Family history tubercular. Duration, six months. Right apex dull above second rib in front and angle of scapula behind; expiration slightly prolonged; mostly dry râles in this region; voice-sounds, especially at right apex in front, increased; râles of same character in left upper front.

Examination with fluorescope: On right side darker than on left from second to fourth rib; diaphragm moves on right side 1 inch, on left 1¼.

12. G. H. Tuberculosis. Both apices dull in front; right more so behind; respirations harsh, moist and dry clicks after cough; tubercle bacilli found.

Examination with fluorescope: Upper half of right lung darker than normal, and apex of left lung.

13. N. E. Tuberculosis. Tubercle bacilli found; deficient resonance over left front; fine crepitations over lower half of right axilla, over upper two-thirds of scapula, and between scapula and spine; numerous squeaks which seem close to the ear; a few also heard between border of right scapula and spinal column; few fine râles at right base.

Examination with fluorescope: Whole of both lungs somewhat darker than normal; the darkest portions are from right apex to second rib, left apex to third rib.

14. P. D., 48 years. Tuberculosis. Duration, two months. Fair resonance over both lungs except at left base behind, where there is slight

dulness; respiration somewhat jerky over upper half of both fronts, slightly bronchial over upper half of left; over left front to the fifth rib are numerous medium and fine moist râles after cough; a few râles over upper right front; at left base are numerous fine crepitations Tubercle bacilli found.

Examination with fluorescope: Left lung darker throughout than right; outline of diaphragm and of heart on left side ill-defined; lower portion of left lung (below a line running directly outwards from junction of fifth rib and sternum) is much darker than above this.

15. D. J. D., 32 years. Tuberculosis(?) Bronchitis. Pleurisy. Considerable expectoration, loss of flesh, pain in left side, flatness at left apex above the clavicle; a little dulness just below outer end of left clavicle; slight dulness above right clavicle; patient breathes feebly on account of pain in lower left chest; increased vocal resonance at left apex, and in small patch below and just outside right nipple; moist râles throughout upper left chest.

Examination with fluorescope: Left side a little darker than right side down to third rib; movement of diaphragm on left side ¾ inch, on right side 2½ inches.

16. C. M., 45 years. Tuberculosis. Fair resonance over right chest, some dulness over left chest, with many fine, moist, sonorous, and sibilant râles, also occasional coarse moist râles; slight increase in vocal fremitus throughout the left side and whole upper chest front and back.

Examination with fluorescope: Left apex as far as lower border of second rib is a little darker than corresponding portion of right side. Diaphragm on right side moves 2½ inches, on left 1¾.

Second examination with fluorescope, seven weeks later: Right clavicle seen only indistinctly; first and second ribs seen less distinctly than normal; diaphragm moves 2¼; left, no clavicle seen; first and second ribs indistinctly; diaphragm moves 1¾.

17. G. A., 35 years. Tuberculosis. Good resonance on right chest except at apex, where resonance is lacking; breathing is rather high pitched, and there is an occasional crackling râle after cough; left lung resonance high pitched at apex, becoming markedly dull below on front and back; breathing, broncho-vesicular; increased tactile and vocal fremitus and whispered bronchophony; numerous fine, moist, and crepitant râles over whole chest. Tubercle bacilli found.

Examination with fluorescope. On right side from apex to lower border of fifth rib the lung is darker than normal, though the outlines of the ribs are seen. On the left side the lung is dark throughout except between the first and third ribs, where there is a light area which suggested a cavity. The left border of the heart is not seen; the diaphragm on the left side is barely made out.

After the X-ray examination another physical examination gave: left apex: percussion rather high-pitched and tympanitic in quality; breathing amphoric.

18. T. H., 32 years. Ill fifteen days before entrance to hospital; never been ill before. At entrance sputum appears to be merely saliva — no signs in lungs; seventeen days after entrance, dulness at left apex to third rib; prolonged and harsh respiration. Left back: dulness above spine of scapula; harsh breathing; voice-sounds increased; fine crackling râles after cough.

Examination with fluorescope: Left lung dark from apex to fourth rib; outline of heart above fourth rib and the ribs themselves barely visible. Diaphragm moved 1 inch on left side, and 2 inches on the right side.

The following seven cases show a general correspondence between the physical examination and the examination with the fluorescope:

19. C. F. W., 21 years. Tuberculosis. Duration, two and a half years. Right side: marked dulness in front to second space, where note becomes higher pitched. At second space respiration somewhat amphoric, with loud crackling râles and metallic tinkling at times; fine râles to base; fremitus and voice-sounds increased throughout; in back, dulness from apex nearly to base. Left side: resonance slightly diminished at extreme apex front and back, with dry râles in front.

Examination with fluorescope: Right side dark to lower border of fifth rib in mammary line. Left side clear except at apex, but as right side is dark, there is no opportunity for comparison with normal. Diaphragm on right side moves ¾ inch only; on left side, 1¼ inches only.

20. M. J., 44 years. Tuberculosis. Lungs: slight dulness at right apex in supra-clavicular space; high-pitched breathing; occasional crackling râles after cough; left side: in front, marked dulness at apex and in left axilla, with percussion note lacking over rest of left front; at apex, breathing is broncho-vesicular with increased vocal and tactile fremitus; numerous fine, moist, and crackling râles.

Examination with fluorescope: Difficult to estimate condition of right apex, as there is no opportunity for comparison with the normal; whole of left side darker than normal. First, second, third, and fourth ribs and clavicle not seen; below this ribs faintly seen. Diaphragm only faintly seen on left side; moves right side only 1½ inches.

21. C. J., 29 years. Tuberculosis. Dulness over right lung down to fourth rib in front and as far as spine of scapula in back; broncho-vesicular breathing; increased vocal and tactile fremitus; bronchophony; numerous fine, moist râles.

Examination with fluorescope: Right side darker to third rib, very marked; moves diaphragm right side ¾ inch, left side 1½ inches.

22. L. C. F., 24 years. Had pleurisy on left side two weeks ago. Pulmonary tuberculosis. Right side negative; left, slightly diminished resonance throughout lower half of left back; voice and fremitus also

diminished, with occasional friction; no râles heard; rest of lung negative. Tubercle bacilli found.

Examination with fluorescope: Right apex seems a little darker than left apex as far as lower border of second rib; diaphragm moves 1⅞ inches on right side, 1⅛ on left side; outline of diaphragm on the left not quite as clear as on right side.

23. H. J., 33 years. Cough one year. Pain in lower front chest; slight dulness at left apex, front and back; occasional râles; voice-sounds slightly increased; prolonged expiration. Tubercle bacilli found.

Fluorescope: One week later, upper part of both right and left chest darker as far as second rib; clavicles and first and second ribs not seen; movement of diaphragm on right side, 2¼ inches; on left side, 1½ inches.

24. C. J., 33 years. Tuberculosis. Duration of illness, two months. Right front by percussion tympanitic; respiration diminished; few râles scattered throughout; tactile fremitus diminished; right back: dulness from apex to one inch below angle of scapula; fremitus same as left side; respiration diminished throughout, less marked from angle down: few fine râles over upper half; entire right back is dull, dulness increasing downwards; left front negative save for few sonorous râles at base; tubercle bacilli found.

Examination with fluorescope: Right side much darker than left side, which is clear and bright; the darker area extends over whole of right side.

25. B. M., 30 years. Tuberculosis, haemoptysis. Tubercle bacilli. Left lung: dulness in front second rib, with bronchial respiration, and a few fine râles throughout the left back; dulness also in lower left back; increased vocal fremitus; right lung free except for small patch in back, opposite fourth dorsal vertebra, over which are heard bronchial breathing and occasional fine râles.

Examination with fluorescope: Left lung darker from apex to fourth rib; right lung darker from apex to lower border of second rib.

Examination with the fluorescope suggested a more favorable condition than was indicated by the physical signs:

26. N. O., 27 years. Tuberculosis (?) Resonance and respiration fair on both backs; right back below spine of scapula, dulness; breathing diminished; vocal and tactile fremitus increased slightly; occasional râles.

Examination with fluorescope: Both sides clear.

27. M. C., 29 years. Tuberculosis (?) Loss of flesh and appetite; for six weeks cough and expectoration; no dyspnoea, no night-sweats. Three examinations for tubercle bacilli negative.

Examination with fluorescope: No difference in two sides; rays

go through both chests well; outlines of diaphragm and heart show clearly.

Later the signs of bronchitis cleared up.

28. S. B., 20 years. Diagnosis: phthisis. May 1, 1894, pain in chest, subject to colds; weak amenorrhoea, signs of consolidation at both apices, especially the left; numerous fine and medium râles. October 16, 1894, signs at both apices; weight, 105½ pounds. December, 1894, weight, 105 pounds. July, 1895, slight dulness at both apices, front and back; few râles; weight, 102 pounds. September, 1896, cold hands and feet; no cough; pain in chest, side, and back, especially after taking any food or drink; patient is very nervous woman.

Examination with fluorescope: No difference in the two sides, both clear; ribs and clavicles stand out clearly.

In the following cases the examination with the fluorescope gave less information than the physical examination:

29. B. J., 42 years. Tuberculosis. Dulness in both supra-clavicular spaces, especially the left; left back dull above the spine of the scapula; below left clavicle some slight dulness with high-pitched breathing, tubular in character with prolonged expiration; vocal and tactile fremitus increased; numerous crackling râles; right apex, dulness to supra-clavicular space; occasional râle at right apex.

Examination with fluorescope: Left apex darker than right apex; no increased darkness detected at right apex; probably not as readily noticed, as the left side is already diseased, and therefore comparison with a normal lung could not be made.

30. L. M. Tuberculosis. Tubercular family history. Haemoptysis, cough, pyrexia; dulness in right front down to fourth rib, with prolonged expiration, increased voice-sounds, fine crackling râles, most marked after cough; dulness over whole right back, with increased tactile and vocal fremitus; left apex dull in front and behind, with high-pitched respiration and crackling râles.

Examination with fluorescope: Both apices darker than normal; darkness more extensive in the right side.

Pneumonia offers an opportunity of testing the value of the X-rays in recognizing increase in density in comparison with the usual physical examination. I have examined patients while they were convalescing from pneumonia, both by auscultation and percussion and by the fluorescope on the same day, and while by means of the latter I was able to recognize that the lungs were denser than normal, I failed to detect the continued increase in density by auscultation and percussion. As the lungs improved the areas that had

been dark became lighter in the fluorescope, until finally the amount of light passing through them appeared about normal. During all this time the movement of the diaphragm was less than normal: that is, the expansion of the lungs was restricted, but increased as the condition of the lungs improved. When I could no longer recognize increase in density in the lungs with the fluorescope, I could easily see by means of this instrument that the diaphragm did not descend to its normal limit, thus showing that the lungs were still in an abnormal condition. Later, the normal limit was reached.

The following cases of pneumonia taken from those I have examined show a general correspondence between the physical signs and what was seen in the fluorescope, but the brief description of these cases does not present to the mind how much these examinations conduce to a more accurate estimate of the condition of the lungs in some cases than has hitherto been possible in any other way. This method of examination enables us to judge better than any other way when the lungs have "cleared up" after an attack of pneumonia, and I am satisfied that it gives us the means of recognizing an increased density in the lungs in pneumonia earlier than has been previously possible:

1. B. G., 36 years. Pneumonia. Ten days before entrance to hospital, sudden pain in left axilla, cough, dyspnoea, fever. Physical examination at entrance showed that there was dulness in left back one inch below spine of scapula, which extended downward and outward to axilla; over dull area bronchial breathing, increased voice-sounds, and tactile fremitus; numerous fine râles after cough; resonance good over both fronts and axillae. Physical examination nine days later, at time of X-ray examination, showed dulness in left back from mid-scapula down, with bronchial breathing, increased voice-sounds, and a few medium râles.

Examination with fluorescope: Left side from third rib downwards so dense that no outline of heart, ribs, or diaphragm is to be seen. The apex of the heart, although not seen, is felt in normal position, showing that the increased density observed in the fluorescope is due to changes in the lungs rather than to fluid in the pleural cavity; right side perfectly clear, ribs and outline of diaphragm seen well.

2. L. B., 19 years. Pneumonia. At entrance to hospital, on the fifth day of the disease, marked dulness over upper right chest, down to fourth rib. Bronchial breathing, increased vocal and tactile fremi-

tus, dulness in right axilla. Right back: dulness from apex to middle of scapula. Left: front and back good resonance; many fine, coarse, and moist râles at base and back. On seventh day of the disease, right front dull from apex to lower border of second rib, shading to lower border of third rib; in back, dull to 2 inches below spine of scapula. Nineteenth day of disease, physical signs have cleared up.

Examination with fluorescope: On seventh day of disease, right lung dark from middle of first intercostal space to fourth rib; the upper and lower border of this dark area were definitely marked; outlines in chest rather less clear than normal on both sides. Diaphragm moved ¼ inch on right side, and 1⅛ inches on left side. Fifteenth day of disease, diaphragm moved 1 inch on the right side; 2½ inches on left side. Nineteenth day of disease, diaphragm moved 2 inches on right side; 2¾ inches on left side. Original dark area on right side not so bright as other portions of the lung. On the twenty-second day of the disease, diaphragm moved 2½ inches on right side, and 3 inches on left side.

3. Q. T. D., 32 years. Pneumonia. Three days before entrance to hospital, pain in right side and back and across the chest. Chills, sweating, fever, some dyspnoea. At entrance, slight dulness in right lower back, and diminished breathing at extreme base. Few fine and coarse moist râles scattered over both backs; otherwise good respiration and resonance over all. A few days later, expectoration rusty. Diagnosis before entrance to hospital was pleurisy with effusion.

Examination with fluorescope: Upper lobe of right lung darker than normal. Left side clear. Diaphragm moved 1 inch on right side; 2¾ inches on left side. Four days later, movement on the right side was 3 inches; on left side, 2¾ inches. Right side perfectly clear. Auscultation and percussion did not show the location of the disease, but it was revealed by the fluorescope. It was largely a central pneumonia.

4. C. A., 27 years. Pneumonia in the upper portion of right side. Eighteen days after entrance to hospital, percussion over front of the chest on both sides was good. In the right back, fremitus slightly increased from apex to angle of scapula; respiratory murmur shorter and fainter than on left. Respiration below angle of scapula on the right side better than above. Percussion over right and left back good.

Examination with fluorescope: Eighteen days after entrance, whole of right side darker than left side; outline of ribs seen only faintly; diaphragm moved ½ inch. Left side rather darker than normal, from second to fourth ribs; diaphragm moved 1⅛ inches. Two days later, right side not quite so clear as left; diaphragm moved 1½ inches on right side, and 2 inches on left side.

5. S. N. Pneumonia. Attack began one week before entrance to hospital. Two weeks after entrance: Dulness in right back from middle scapula down, and in axilla from fourth rib down; breathing somewhat bronchial; numerous coarse and medium râles; voice-sounds increased over this area.

Examination with the fluorescope: Right side less clear throughout than the left side, but especially below the lower border of second rib, where the outlines of the ribs are much less clear, the outline of the diaphragm is not seen. Left side clear; outline of heart, ribs, and diaphragm well defined.

6. G. W., 23 years. Pneumonia of left lower lobe. Attack began three days before entrance to hospital. At entrance, dulness in left back from 1½ inches above angle of scapula, this line of dulness extending down and out to axilla at the seventh rib; over dull area bronchial breathing, tactile fremitus, and increased voice-sounds; no râles. Six days after entrance, at time of X-ray examination, breathing a little diminished at lower part of left back; fine râles at extreme base in front, in axilla, and in back; night-sweats; loss of flesh; haemoptysis.

Examination with the fluorescope: Left side darker than normal below the level of the fifth rib in mammary line; outline of heart on left side obscured, and outline of diaphragm not clearly made out; right side darker than normal from second to fourth rib.

7. C. J. Pneumonia. Attack began one week before entrance to hospital. At entrance, slight dulness in right back from angle of scapula down, with fairly numerous medium and fine râles; one week later, breathing over lower third of right back diminished, which is dull to percussion.

Examination with the fluorescope: Right side below lower border of third rib darker than normal; outline of diaphragm on right side barely visible; on left side very clear.

In the following case what was found at autopsy confirmed what was seen in the fluorescope:

8. S. J., 61 years. Examination with fluorescope: Apex of right lung not as clear as lower part. Left side dark throughout; no outlines of heart, rib, or diaphragm seen; right border of heart two inches to right of sternum.

Autopsy, one week later: In upper lobe of right lung, the tissue retracted; in apex, small caseous nodule found; pericardium dilated, filled with opaque yellowish fluid, and extended to right nipple line; heart enlarged in all its cavities. Left lung: entire posterior portion of lower lobe and large portion of upper lobe in a state of red pneumonic consolidation.

The observations already referred to, namely, that the amount of rays passing through the lungs on to the screen of a fluorescope is not the same throughout the whole of the respiratory cycle, that so small an amount of water as ½ inch

obstructs the passage of the X-rays sufficiently to be seen in the fluorescope, the radiographs of the diseased lungs, and the cases I have given, demonstrate that we can recognize increase in density in the lungs by means of the X-rays, and therefore their serviceableness in lung diseases. The clinical test is, of course, the crucial one. The abnormal condition of the lungs in tuberculosis and pneumonia may be shown not only by the obstruction which they offer to the passage of the rays, but also by the restriction of the excursion of the diaphragm. In some cases the latter is a more delicate test.

In pleurisy with effusion we can estimate the amount of fluid in a general way by the amount of light which passes through the thorax. When the effusion is large no more rays pass through it than through the liver, and the outlines of the diaphragm, ribs, and heart are obliterated on the side of the effusion. If there is a smaller amount of fluid the outlines of some of the upper ribs are seen, and with a small effusion the outlines low down in the thorax only are ill-defined. The fluorescope assists us to distinguish between an effusion and a thickened pleura. In some cases of effusion the fluorescope shows us displacement of the heart, to the left when there is a large effusion on the right side, and a much greater displacement to the right, and this displacement is of more frequent occurrence, when the effusion is on the left side. This displacement of the heart to the right may not be recognized by percussion even when it has been pushed much beyond its normal place. In one patient the heart was seen to be displaced more than two inches to the right, but no displacement was detected by percussion. While examining some cases of pleurisy with effusion by the fluorescope, I have found indications of tuberculosis in the lung where it was not previously suspected.

Sixteen cases of pleurisy with effusion, seven on the left and nine on the right side, and one dry pleurisy.

In one of the seven cases of pleurisy on the left side the

examination with the fluorescope showed that the heart was not displaced to the right, in five that it was displaced to the right, and in one there was no record.

In six of the nine cases of pleurisy on the right side the examination with the fluorescope showed that the heart was not displaced, in two that it was displaced, and in one there was no record.

In Cases 5 and 8 the increased density of the lung and the limited excursion of the diaphragm suggest tuberculosis.

In Case 9 the diagnosis by physical examination was pleurisy with effusion or thickened membrane, the examination with the fluorescope showed that it was pleurisy with effusion.

Five cases of pleurisy on left side with displaced heart:

1. D. J., 40 years. Pleurisy with effusion. November 4, three pints drawn from left side. Left side, dulness begins at second rib in front, becoming flat at fifth rib; dulness in back at spine of scapula; flatness at angle of scapula; breathing and tactile fremitus lost just above angle; right side normal.

Examination with fluorescope: November 9, whole of left side dark, no ribs seen, neither is the heart nor the outline of diaphragm. Right side: apex darker than normal above second rib; movement of diaphragm 2¼ inches; right border of heart displaced 2½ inches to right of sternal border. This condition percussion did not show.

2. V. H., 13 years. Dulness over left front from third rib down; hyper-resonant above third rib; dulness throughout left axilla, becoming flatness over lower half; in axilla voice-sounds and tactile fremitus are diminished over dull and lost over flat area; dulness in left back from spine of scapula, becoming flatness at about the angle; tactile fremitus diminished over dull area; voice-sounds increased; whispered and spoken sounds heard distinctly to base; breathing somewhat diminished, but bronchial in character, and heard nearly to base; left side, a few coarse râles over upper left front; no râles in back; numerous fine crepitations in lower right axilla.

Examination with fluorescope: Left side dark; outline of heart and diaphragm not seen on left side; only first and second ribs seen. Right side, outline of ribs and diaphragm seen clearly; heart displaced to right, extends 2½ inches to right of sternum. Fourteen days later, left side clear above outline of left border of heart, which is faintly seen; heart not displaced.

3. B. G., 21 years. Pleurisy with effusion. Dulness on left side in front from third rib; in back, from mid-scapula, becoming flatness at

angle. In back, breathing and tactile fremitus are diminished from above downward, being lost about 1 inch below angle of scapula: voice-sounds heard faintly nearly to base. Heart: apex not felt; left border not determined; right side of heart is at right sternal border.

Examination with fluorescope: Right side normal; left side dark below second rib; no outline of ribs, heart, or diaphragm to be seen; heart displaced to the right 1¼ inches beyond the sternal border on a level with the nipple. This fact could not be made out by percussion; there was good resonance by percussion up to and rather inside of right sternal border.

4. G. J., 24 years. Pleurisy with effusion. On left front and axilla dulness below fourth rib; in the back, dulness beginning an inch above angle of scapula; voice-sounds in breathing heard faintly nearly to base; tactile fremitus lost at angle of scapula; on the right side cardiac area extends to 1 inch of right of sternal border.

Examination with fluorescope: Whole of left side darker than right side; no ribs seen except faintly at top of chest; no outline of left side of heart or of diaphragm seen on left side. Heart displaced to right.

5. A. C., 35 years. Pleurisy with effusion. Right lung hyper-resonant throughout; somewhat exaggerated respiration; sonorous, coarse, and moist râles. Left apex: diminished resonance from apex, front and back, increasing to flatness at third space in front, at fourth rib in axilla, 1 inch below spine of scapula in back, fremitus marked above; respiration diminished above, and lost just below line of flatness; friction sounds in back from spine of scapula nearly to angle of same.

Examination with fluorescope: Right side clear except at apex, as far as second rib, where it is less clear than normal. The diaphragm moves 1¼ inches between full inspiration and complete expiration. Heart displaced to the right 1 inch beyond right border of the sternum. The increased density of the lung at the apex and the limited excursion of the diaphragm suggest tuberculosis. Left side dark; clavicle and first rib seen faintly; no outline of heart or diaphragm.

Pleurisy of left side, heart not displaced:

6. H. J., 15 years. Pleurisy with effusion. October 3, dulness an inch below angle of scapula on left side. October 10, fair resonance to tenth rib; few friction rubs still heard. Respiration heard to extreme base.

Examination with fluorescope, October 8: Outline of diaphragm on left side not quite so clear as on right side. Heart not displaced.

7. N. S. Pleurisy with effusion. Two days previous to X-ray examination with fluorescope one quart of clear fluid was drawn from left pleura.

Examination with fluorescope: Left chest above fourth rib darker than normal; below this rib outline of heart and diaphragm hardly visible.

Two cases of pleurisy on right side, with displaced heart:

8. B. D., 31 years. Pleurisy with effusion. Right side, dulness from second space in front and below spine of scapula behind, becoming flat; voice-sounds and fremitus diminished over dull area and absent over flat area; relative dulness from left edge of sternum to just inside nipple line; left lung somewhat hyper-resonant throughout; otherwise negative.

Examination with fluorescope: Right side dark throughout. From apex to diaphragm, ribs barely suggested in the middle of the thorax; darkness on the right side nearly the same as that of the hepatic area; left border of heart ¼ of an inch outside the mammary line; left side: apex to fourth rib dark; diaphragm moves 1½ inches only. The diminished excursion of the diaphragm and the increased density of apex of left lung suggest tuberculosis.

9. M. P. Pleurisy with effusion or thickened membrane

Examination with fluorescope: Right side much darker than left side; ribs not seen below the third rib; outline of diaphragm not seen; heart displaced to left. This examination shows the presence of fluid.

Six cases of pleurisy of right side, heart not displaced.

10. H. N., 59 years. Pleurisy with effusion. Tapped three weeks previously; thirty-seven ounces withdrawn. Right front, flatness from fourth rib down; fremitus lost at sixth rib; distant breathing heard to base; flatness at right back to angle of scapula: breathing and fremitus lost at angle.

Examination with fluorescope: Right chest darker throughout; no outline of ribs or diaphragm seen; left side normal; heart not displaced; diaphragm moves 2½ inches.

11. P. A., 19 years. Dulness in right chest from third rib downward in front, and in axilla, and from mid-scapula downward in back; breathing, tactile fremitus and voice sounds diminished over lower part of dull area; friction rubs heard over upper third of right front.

Examination with fluorescope: Right side dark; neither ribs nor diaphragm seen; heart not displaced to left; left side clear.

12. C. J., 37 years. Pleurisy with effusion. Dulness at both apices in front, with broncho-vesicular breathing; increased vocal resonance and a few crackling râles, especially after cough; dulness over right back, becoming flat 3 inches above angle of scapula; over the upper portion of the lung numerous fine râles; spoken and whispered sounds increased; over the flat area breathing is diminished and nearly absent at base, with diminished vocal and tactile fremitus; dulness in right axilla below fourth rib, with diminished breathing; good resonance and respiration over right front.

Examination with fluorescope: Right side dark, ribs only faintly indi-

cated throughout right chest; outline of diaphragm not seen on right side. Left side clear, heart not displaced, the left border and apex clearly marked.

13. G. M., 23 years. Pleurisy with effusion. Good resonance and respiration over left chest; dulness over whole of right chest, with flatness below the third rib in front and 1 inch below spine of scapula in back; right side, at apex, breathing is bronchial, with crackling and a few moist râles; below, breathing becomes distant, and is nearly absent at the base; a few fine rubbing sounds are heard over the right chest.

Examination with fluorescope, November 5: Left chest normal; right chest, first and second ribs seen faintly; no outline of diaphragm seen; below fourth rib, chest about as dark as the hepatic area; liver not displaced downward; heart not displaced to left. November 12, left chest normal; right chest, outlines of first, second, and fourth ribs seen; outline of diaphragm not seen.

14. G. J., 43 years. Pleurisy with effusion. Dulness, right side below third interspace in front, soon running into flatness; behind dulness begins about mid-scapula; left side negative.

Examination with fluorescope: Right side, first and second ribs seen, but not very distinctly, and no outline of diaphragm; heart not displaced to left; left side normal; ribs and spleen and heart seen well.

15. E. C. Pleurisy with effusion. Dulness from spine of scapula on right and below fifth space in front; visible respiration almost entirely on left side; heart not displaced.

Examination with fluorescope: Whole of right side darker than left side; border of the diaphragm on the right side is not so well marked as on the left side, where it is clearly defined; ribs on right side do not stand out so distinctly as on left side.

16. H. E. M. Pleurisy with effusion. The day before the X-ray examination was made the chest was tapped and about one quart of fluid was drawn off from right side.

Examination with fluorescope: Right side darker than left side, but not uniform in character. The area above an imaginary line running from the point where the cartilage of the sixth rib joins the sternum to the outer end of the clavicle, although darker than the left side, was lighter than the area below this line. Percussion showed less dulness above this line than below it. The outline of the diaphragm on the right side was indistinctly seen. No record as to heart.

17. D. D. Dry pleurisy on left side.

Examination with fluorescope: Both sides of chest equally clear. The diaphragm moves well in respiration.

Two thoracic aneurisms are represented in the figures 8, 8′, 9 and 9′ by lines on the skin which follow the outlines as

Fig. 8. — Aneurism — front of chest.

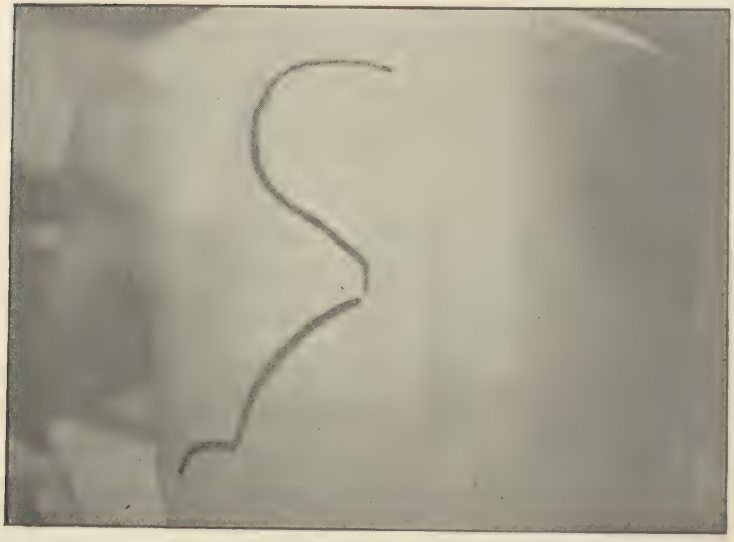

Fig. 8. — Aneurism — back.

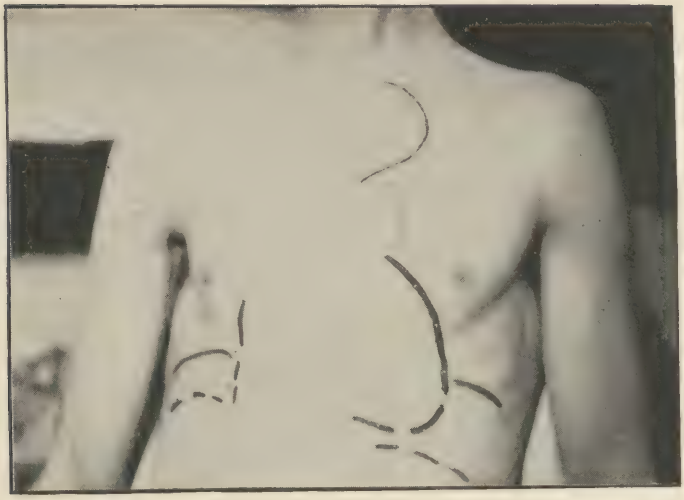

Fig. 9. — Aneurism — front.

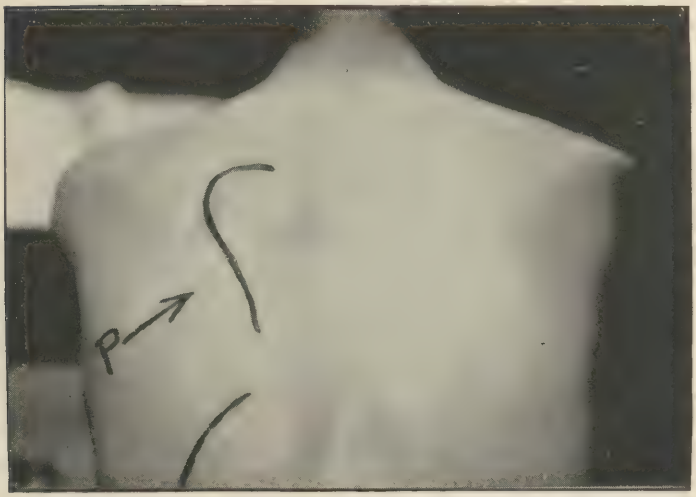

Fig. 9'. — Aneurism — back.

seen in the fluorescope. The heart in three of the thoracic cases given below is much displaced. Aneurisms of the arch of the aorta are most clearly outlined when their borders are nearest the fluorescope; those on the left when examined from the back, those on the right when examined from the front. It is obvious that aneurisms of the thoracic aorta can sometimes be detected earlier by X-ray examination than in any other way. In obscure thoracic cases where an aneurism of certain portions of the aorta is suspected, but does not exist, it may probably be excluded by an X-ray examination.

M. J., 59 years. Aneurism. About four years ago the patient suddenly became unconscious for about one minute without warning; recovery was immediate. About one year ago he began to be hoarse, and this hoarseness grew rapidly worse; about the same time, while running, he had marked dyspnoea; this symptom has increased; can walk some distance if careful. About three months ago he first raised a little rather dark blood, and has continued to raise a little blood since then, especially after talking. Within the past months has had short and sharp attacks of pain, starting in the pit of the stomach, radiating to left shoulder, and down left arm to elbow. There is numbness of left arm associated with this pain; voice is shrill and husky; left vocal chord is paralyzed and fixed in the median line; arteries somewhat tortuous and resistant; heart's area decidedly diminished (emphysema); action regular and fairly strong; apex beat in nipple line; first sound in aortic area is rough; second sound is ringing and valvular; resonance of lungs somewhat exaggerated; over upper half of left chest there is respiratory murmur; vocal fremitus and voice-sounds are diminished, especially in front; percussion not modified; faint pulsation to be felt by pressing the chest between the two hands; seems most marked at junction of second rib with sternum.

Examination with fluorescope: The curved lines in the upper part of patient's left chest (see Figs. 8 and 8′), both front and back, and the curved line on his right chest, indicate the outline of the aneurism as seen in the fluorescope. The lower curved lines on his left chest, front and back, mark the outline of the heart; the lowest curve on the left back and the right front, part of the outline of the diaphragm; the dotted line, the cardiac area as determined by percussion. This shows how a large aneurism may exist in the chest without giving rise to physical signs. Some weeks after the return home of the patient he took a twenty-mile drive, contrary to the direction of his physician, immediately after which the aneurism burst, and he died in a moment.

F. K. Aneurism. The illustration of this aneurism is not given; its character was similar to that of M. J.

C. S. T. Aneurism: Four months previous to entrance to hospital the patient complained of pain in the right shoulder and elbow, which was followed a week or two later by pain in the chest over a pulsating area on the right side in front.

Examination with fluorescope: The aneurism in front on the right side was easily recognized by percussion, but on the left side in front there was no dulness to percussion over this area of the aneurism, but it was seen in the fluorescope. The presence of the aneurism was obvious, but its extent could only be determined by the fluorescope.

K. B., 44 years. (A patient of Dr. F. C. Cobb, kindly referred to me by Dr. E. C. Codman.) Aneurism. Lost his voice very suddenly about two weeks before he was examined; has pain in left shoulder for two or three seconds at a time.

Examination with fluorescope (see Figs. 9 and 9′): The upper curved line, front and back, marks the outlines of the aneurism as seen through the fluorescope, and were drawn by me on the patient's chest. In the view of the back (Fig. 9′) the arrow marked P indicates the point where pulsation was most marked; the right and left border of the heart are also marked on the chest (Fig. 9), and the left border in the back (Fig. 9′); the parallel lines drawn on the chest in front are the outlines of the diaphragm in full inspiration and complete expiration.

C. A., 40 years. Aneurism. Pulsation seen and felt in the lower part of the neck above and behind the inner end of the right clavicle. There was evidently an aneurism of the subclavian artery. An operation was advised, but before this was done an X-ray examination was made in order to determine the lower limit of the aneurism and ascertain if it extended to the larger arteries below; in which case an operation would be more serious, or it might be necessary to abandon it altogether.

Examination with the fluorescope: No indication of any aneurism extending below the lower border of the clavicle. A radiograph showed the outline of the aneurism in the neck, but also gave no indication of any below the clavicle. Both sides of the chest were equally clear, thus showing there was no aneurism there. Operation for ligaturing the innominate artery confirmed the observations made by X-ray examination.

The position and size of the heart are not always indicated correctly by percussion, and the apex beat cannot always be felt, and even where this is readily felt X-ray examinations show that it does not correspond in all cases to the apex of the heart as seen in the fluorescope. The lower border of the heart cannot be obtained by percussion, but can be seen in the fluorescope during deep inspiration; in some patients nearly the whole outline of the ventricles can be seen. The right and left border of the heart may

usually be more correctly determined by the fluorescope than by other means.

In some cases of emphysema the outline of the heart is not found by the ordinary examination, but is seen with more than normal clearness by the X-ray examination. If in some cases we are unable to establish the position of the heart exactly by auscultation and percussion, it is obvious that we may be still less able to determine its size. In studying diseases of the heart, the fluorescope is of assistance in determining its size and position, also in determining increase in density of the lungs due to oedema or marked congestion, the result of cardiac or other diseases. The fluorescope may show that the lungs of a patient suffering from cardiac disease or dyspnoea on exertion are less clear than normal, and after suitable treatment the dyspnoea disappears and the lungs become clear, thus confirming the information obtained by the fluorescope.

The Roentgen rays enable us, then, to gain a better knowledge of the size and position of the heart, and to understand better not only the condition of the heart, but that of the patient also; in other words, they add to our knowledge of diseases of the heart and some of the conditions that accompany them. In passing let me say that there are a number of other diseases or conditions that may bring about changes in the thoracic cavity, the information of which obtained by means of the fluorescope may enable us to form a much better estimate of the patient's condition than would otherwise be possible.

I should be glad to take up examinations of the heart more fully, were it not that the importance of the subject demands more space than is now at my disposal.

In emphysema the lungs are unusually clear and their volume is increased. The heart is seen in the fluorescope more clearly than normal, although by percussion the outline cannot be determined. The diaphragm is seen to be lower than normal, and the excursion which it performs between deep inspiration and expiration to be less than normal. The heart also may lie lower than in health, and in the later stages in a more vertical direction. The lower position and the more limited excursion of the diaphragm

give a means of making a diagnosis of this condition probably earlier than has hitherto been possible, or in some cases the lack of these signs enables us to exclude it. Case B. F. suggests that there was no emphysema, although this was the diagnosis made from physical signs.

1. G. P., 55 years. Diagnosis: Pleurisy with chronic bronchitis; subject to asthmatic attacks and cough for years; caught cold two weeks before entrance to hospital. Physical examination: Severe cough with

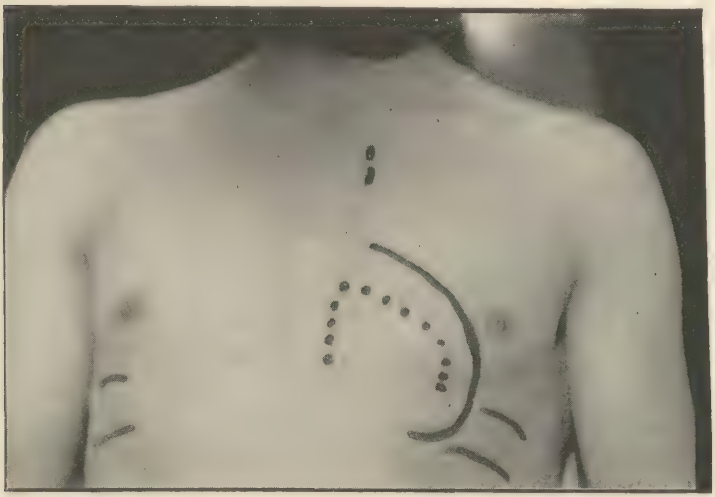

FIG. 10. — Emphysema. Diaphragm lines lower and nearer together than normal. Dotted line indicates cardiac area by percussion. Broken line under inner end of left clavicle shows arch of aorta.

pain in left chest, with marked dyspnoea; lungs hyper-resonant throughout; respiration everywhere harsh, with many râles, fine, squeaking, sibilant, and coarse; expiration somewhat prolonged; friction rub in left axilla below fifth rib; respiration slightly diminished; heart negative; outline not found by percussion; no apex beat.

Examination with fluorescope: Diaphragm lower down in the chest than normal and the excursion 1¼ inches only. Outline of heart shown distinctly. The position and limited excursion of the diaphragm and the fact that the outline of the heart could not be obtained by percussion indicate emphysema.

2. G. J., 33 years. Emphysema and aortic regurgitation. Heart: dulness from left sternal border to just inside nipple line. Good resonance throughout the lungs; sibilant and sonorous râles.

Examination with fluorescope: The full line (see Fig. 10) indicates

a part of the cardiac area as seen in the fluorescope, the Crookes tube being 20 inches distant therefrom; the dotted line, the cardiac area as found by percussion. A comparison of these two lines shows that the fluorescope revealed more in regard to the size and position of the heart than was obtained by percussion.

3. M. A. J. Emphysema. Lungs hyper-resonant over all on percussion. Inspiration and expiration prolonged. Fine and coarse bubbling râles. Heart's area obscured by hyper-resonance of chest.

Examination with fluorescope: The diaphragm on both sides reaches the highest point at the sixth rib in the mammary line. Heart lower down in the chest than normal, but clearly seen; left border ¾ inch inside mammary line; right border 1¼ inches to right of sternum on level with nipple. Apex in fifth space.

4. B. F. Diagnosis: Emphysema with asthma. Examination with fluorescope: Diaphragm moved on the right side two and one-half inches, and on the left side three inches. This excursion of the diaphragm being normal suggests that there is no emphysema present.

In pneumo-thorax, hydro-thorax, and oedema of the lungs the fluorescope is of service; some partial oedema of the lungs is, I am inclined to believe, a more frequent condition than I had supposed. On first examining a patient of this latter class, his condition being unknown, I was surprised to find how difficult was the passage of the rays. I was at a loss when I found the picture of the patient's thorax in the fluorescope was unusually dark, and supposed something was wrong with my Crookes tube, but after trying another I realized that the patient's chest was denser than normal; the tube was not in fault. I give the following cases to illustrate the aid the fluorescope renders in oedema of the lungs; the fluorescope showed this condition when it was not made out by physical signs:

C. E., 47 years. Diagnosis: Chronic diffuse nephritis and cardiac. Three months previous to entrance to hospital patient complained of increased dyspnoea, fluttering of heart, and faintness; later, feet swelled in morning. Physical examination on entrance: atheromatous arteries; heart extended from one and one-half inches to right of median line to eight inches to left of line; apex beat in eighth space; no murmurs. Lungs: Dull in both backs below angle of scapula; over these areas breathing is diminished and accompanied by numerous fine râles. Ten days after entrance, feels less well and complains of dyspnoea. Eleventh day after entrance, Roentgen ray was tried on patient, but was not thrown through the chest, and the cause was thought, by Dr. Williams, to be

marked oedema of the lungs, but examination shows only a few moist râles at bases. Heart: At apex a rough systolic murmur is heard. Nineteenth day after entrance, eight days later, patient suffers a great deal from dyspnoea, sits up in bed nearly all the time, night and day. Pulse on twentieth day very weak; marked cyanosis; dyspnoea; death at 3.30 P.M.

Examination with fluorescope, eleventh day after entrance: First and second ribs can be fairly well made out on both sides. No outline of any ribs except the upper ones can be distinguished; lungs below the third rib are much darker than normal; no outline of diaphragm on either side to be seen; heart not seen. This examination, in connection with the physical signs, indicates oedema of the lungs, with, perhaps, some hydro-thorax.

C. J. J. Diagnosis: Chronic diffuse nephritis; cardiac dilatation. Dyspnoea on exertion; swelling of the feet; orthopnoea. Lungs: No dulness; moist râles heard over both bases, front and back; bronchitis and dyspnoea; improved under treatment.

Examinations with fluorescope: Ribs seen, but less distinctly than is normal; outlines of diaphragm and heart not sharply defined; heart considerably enlarged to the left. This examination, together with physical signs, indicates oedema of the lungs sufficient to increase their density and make the outline of the ribs and neighboring organs ill-defined.

It will prove instructive to study by means of the fluorescope cases of dyspnoea on exertion, and note the amount of congestion or oedema of the lungs accompanying them.

In some cases of bronchitis the lungs appear less bright in the fluorescope than in health, but in others this is not the case.

It not infrequently happens that the physician or patient fears the latter has some serious or obscure disease of the chest. In such cases, of the various methods of examining the lungs there is no one which gives such good evidence that they are free from serious disease as the examination with the fluorescope.

The foregoing observations and cases show that by X-ray examinations of the chest we gain assistance in recognizing a density greater than normal, in tuberculosis, pneumonia, infarction, oedema, congestion of the lungs, in aneurism, and in new growths; they likewise assist us to recognize fluid in the pericardial and pleural sacs. The distribution, location, and amount of this increase in density which the

fluorescope shows assist us in some cases to differentiate these diseases and conditions. Diminution of the normal density, which is the result of emphysema and pneumothorax, is indicated by the position and movement of the diaphragm; a certain curve of the diaphragm is characteristic of this latter condition. The excursion and position of the diaphragm are of assistance in determining the condition of a lung or lungs in tuberculosis, pneumonia, and other diseases. As is the case with all other observations on which a diagnosis is founded, the conditions which are revealed by the fluorescope are only to be properly interpreted after experience in making X-ray examinations has enabled the physician to give these observations their due weight.

I have already referred in a previous article to the experiments made at the Massachusetts Institute of Technology on the action of the X-rays upon several forms of bacilli. The rays in these experiments had no effect on the bacilli.

I shall preface the following surgical cases by a few brief suggestions only, which may be of assistance to those who are beginning to use the X-rays in surgical cases.

The character of the radiograph depends, to a considerable extent, upon the length of the exposure. Too long an exposure will show an excellent picture of the bones, but not the soft parts; a shorter exposure may give bones, muscle, fat, etc.

A more satisfactory examination of the leg and forearm can be made with the fluorescope than of the thigh, for example, because in the former the bones lying closer to the surface are nearer to the fluorescope, and therefore their outlines are more sharply defined than those of the femur or hip-joint. These latter are better seen with a strong light at some distance from the patient. In passing it may be of interest to note that in the examination of the hip-joint it is an advantage to have the patient lying on his face.

Fractures with displacement of the bone can be readily made out by means of the fluorescope; when, however, there is fracture with only slight change in the outline it is

not readily detected by this means, but may be found more certainly by a radiograph. The fluorescope sometimes gives a better appreciation of the conditions in fractures with sufficient displacement, because by turning the part it may be seen from more than one side. The fluorescope also enables the practitioner to use both eyes and hands; that is, the part may be examined by the hand while observing it through the fluorescope. This enables him to determine, for instance, that a given induration is not bony, although it feels as if it were.

In examining the extremities it is well to compare the diseased with the healthy one; for example, the outlines of tuberculous joints, and especially the ends of the bones near them, are obscured instead of being sharp in outline; the diseased bones seem larger, but not so dark as the healthy bone. There appears to be less of inorganic salts in the diseased than in the normal bones, and more inorganic salts in the tissues surrounding the diseased bones than in the corresponding parts on the normal side. Whenever possible it is advisable to place both the healthy and the affected extremity side by side under a large fluorescope.

A radiograph of a cancer of the breast, taken after removal, showed the diseased portions were more resistant to the rays than the healthy tissues.

NEEDLES, BULLETS, AND GLASS.

1. Piece of needle in ulnar side of hand.

Fluorescope and radiograph showed needle, which was removed by surgeon.

2. Two bullet wounds, one about 2 inches posterior to large trochanter of right femur, second over last lumbar vertebra, about 1 inch to left of median line.

By fluorescope, one bullet located on inner side of right thigh, 2 inches below pubes; removed by surgeon. Second, just above the left sacro-iliac synchondrosis. [Allowed to remain.]

3. Bullet wound of right shoulder.

Bullet located by fluorescope and removed by surgeon.

4. Piece of needle in left knee.

Located by fluorescope over inner tuberosity of tibia; removed by surgeon.

5. Piece of needle in hand four weeks ago.
Located by fluorescope and radiograph; removed by surgeon.

FIG. 11. — Radiograph of hand, showing that the enlargement of the ends of fingers was not due to changes in the bone.

6. Bullet in thigh.
Located by fluorescope; removed by surgeon. Had been searched for unsuccessfully outside the hospital.

7. Piece of needle in thenar region.
Located by fluorescope; removed by surgeon.

8. Piece of needle in toe.
Seen in fluorescope; not found by surgeon.

9. Bullet wound in groin.
Fluorescope located bullet in thigh; removed by surgeon. Previous unsuccessful search before entrance to hospital.

FIG. 12.—Epiphyses of femur and tibia.

10. Small wound in calf of right leg, probably from piece of cartridge exploded on car track.
Small piece of metal (copper) located in leg; removed by surgeon.

11. Piece of needle in foot.
Located by fluorescope; removed by surgeon.

12. Bullet in left thigh.
Located by fluorescope and radiograph; removed by surgeon.

13. Piece of needle in right hand.
Located by fluorescope; removed by surgeon.

14. Small bit of glass in finger.

Fluoroscope showed nothing; radiograph showed triangular piece of glass about ⅛ inch the longest way. See Fig. 18.

15. Bullet wound of back.

Shot in left back over scapula. Bullet located by fluoroscope and found in right back under scapula.

With the fluoroscope held against the back, the patient lying on his face, considerable movement of the Crookes tube from side to side gave very slight movement of shadow of bullet, thus showing that it was near the surface of the back.

Removed by surgeon.

16. Congenital malformation of toes.

Radiographed.

17. Necrosis of ileum.

Radiograph showed roughened outline of ileum.

18. Necrosis of tibia.

Fluoroscope shows lighter area in tibia about 3 inches long, beginning about 1 inch above ankle, at the upper end of this a light area ⅜ inch in diameter. Radiograph also shows the same. Appearances confirmed at operation.

19. Tubercular knee.

Fluoroscope: outline of left knee-joint not defined. Head of tibia larger. Radiograph shows the same. Appearances confirmed at operation.

20. Osteo-sarcoma of humerus.

Fluoroscope and radiograph show distinctly great enlargement of humerus and shaggy outline. See Fig. 16.

21. Osteo-myelitis of right humerus.

Fluoroscope shows whole humerus thickened and roughened, head of bone involved.

22. Tuberculosis of femur.

Fluoroscope and radiograph show thickened femur.

23. Fracture of patella after wire suture.

Radiographed.

24. Fracture one year old of both bones of leg.

Sinus into which crayons of iodoform had been inserted. Fluoroscope shows fracture and also iodoform which is as well marked as a piece of lead.

Radiographed. See Fig. 14.

25. Tuberculous knee. Left knee considerably swollen, quite uniformly, surface moderately tense, knee held at moderate flexion.

By fluorescope: no outline of knee-joint seen; head of tibia and fibula

Fig. 13. — Old fracture of radius.

and patella not seen; all of these clearly seen in other knee. The radiograph gave the same result. The appearances suggested the presence around the joint of some deposit through which the rays passed less readily than through normal tissues.

26. Fracture of tibia in stout woman.

Seen clearly in fluorescope; seemed in perfect position when examined antero-posteriorly, but the lateral view showed some overlapping.

FIG. 14. — Fracture of both bones of leg which has been dressed with iodoform. This latter obscures the fracture of the tibia. The dark foreign bodies resembling pieces of metal are pieces of iodoform. This radiograph was taken with bromide paper which was then coated with oil, and silver prints were made therefrom.

27. Necrosis of hand.

Fluorescope shows about the third metatarso-phalangeal joint enlargement and bending of first phalanx.

28. Old injury to elbow.

Radiographed.

29. Necrosis of feet after frost-bite.

Radiographed.

30. Exostosis of inferior surface and distal end of third and fourth metatarsal bones about the size of a large pea. Removed by operation.

This enlargement was not seen in the fluorescope; but the patient was a child five years old, and therefore it was less marked than in an adult.

No radiograph taken.

Fig. 15.— Rickets in colored child three years old.

31. Hard, perhaps bony, tumor in popliteal space, marked tenderness to slight pressure; hard swelling, not pulsating.

Fluorescope showed bones and knee-joint normal; examining finger when touching hard and tender point was seen to be at least two inches from bone.

[At operation proved to be vascular tumor about the size of a walnut.]

32. Fracture forearm two years before.
Fluorescope and radiograph showed fracture clearly.

33. Congenital deformity of hand.
Radiograph showed clearly the malformation of bones.

34. Osteo-sarcoma of right femur.
Suppurative periostitis of left fibula.
Fluorescope shows right femur clearly defined, no enlargement Left fibula thickened and not sharp in outline.

35. Fracture of vertebrae.
Radiograph unsuccessful, as plate proved to be a poor one. [Did not fix after development.]

FRACTURE SUSPECTED, BUT NOT FOUND BY THE X-RAY EXAMINATION.

36. Fracture of the radius three inches above carpus, found to be perfectly straight and normal in fluorescope.

37. Fracture of ulna nine weeks old.
Fluorescope showed dislocation of carpal end of radius.

38. Injury of foot; question of fracture of external malleolus or dislocation of bones of foot.
Fluorescope showed nothing abnormal.

39. Child eight years old swallowed a silver twenty-five-cent piece, some years previously; some bronchial irritations since.
Radiograph of whole of upper half of body showed a perfectly normal thorax, and no coin present.

40. Fracture of os calcis. Tenderness and swelling below external malleolus.
Fluorescope did not show any fracture.

41. Needle in palm of hand on previous day.
No needle found by fluorescope or radiograph.

42. Needle in foot two years previously.
Fluorescope and radiograph showed no needle.

43. Suspected injury to elbow-joint.
No fracture found by fluorescope.

44. Colles fracture.
No evidence of fracture in fluorescope.

FIG. 16.— Osteo-sarcoma of the humerus.

45. Recent fracture close to base of first metacarpal, crepitus distinct.

No evidence of fracture found in fluorescope.

46. Fracture of os calcis.

I compared this heel bone with the normal foot under the fluorescope and as a further means of testing the condition of the bone I tried to

FIG. 17. — Bullet in the tibia; just below the bullet small dark spots are seen, which are bits of lead scraped off the bullet in its passage through the bone. This indicates that the bullet was fired from a point below the level of the knee. (The patient dropped his revolver on to the floor, when it went off.) Evidence of this sort might prove serviceable in a medico-legal case.

move the supposed fractured os calcis, while at the same time looking at it with the fluorescope. No fracture was detected.

47. Fracture of metatarsus.
Intense pain, tenderness, arch of foot seems flattened out.
Radiograph showed nothing abnormal.

48. Baby said to have needle in side of abdomen.
No needle seen in fluorescope.

FIG. 18. — Small piece of glass in inner side of little finger.

FIG. 19. — Needle in hand.

49. Sprain of ankle (?)
Fluorescope shows no deformity of ankle compared with uninjured one.

50. Fracture of cervical vertebrae.
Four cervical vertebrae seen in fluorescope; nothing abnormal made out.

51. Fractures of condyles of humerus; question of good position of parts; considerable swelling.
Fluorescope shows position at elbow good.

52. Compound fracture of femur; long suppuration; extreme sensitiveness of femur for several weeks; considerable thickening of femur; question of osteo-myelitis.

Fluorescope shows outline of left femur clearly defined; thickening felt by finger while looking through fluorescope evidently not bony.

53. Question of foreign body in finger.
Nothing shown by radiograph.

54. Question of piece of needle in finger.
Nothing shown by radiograph.

55. Question of injury to bones of hand.
Fluorescope shows no bony injury.

56. Question of renal calculus.
Nothing seen in radiograph.

57. Question of needle in thumb.
Fluorescope and radiograph show no needle in thumb.

58. Question of fracture of shoulder.
No injury seen by fluorescope.

No harmful effects have been received in any way by the patients, more than two hundred and fifty in number, whom I have thus far examined by the X-rays at this hospital, and there need not be the slighest anxiety on the part of the patient if the examinations are made by some one who has had experience and has suitable apparatus. I have seen, however, several persons who have suffered a more or less severe inflammation of the skin, the nails also being sometimes involved, but they were all individuals whose occupation brought their hands into close proximity to the Crookes tube, or who, for purposes of testing its possibilities for harm, had exposed some part of the body to its action at a short distance for a considerable period. But there are simple ways of obviating these effects.

Interesting, not to say magical, as are the physical phenomena connected with the X-rays, we should not be led to assume for them an exaggerated importance in practical medicine. They do unquestionably afford us valuable aid, and through them an advance in our methods of examining patients is obtained. I have thus far found them of especial service in diseases of the chest.

I have had the privilege of studying the physics of the X-rays in the Rogers Laboratory of the Massachusetts Institute of Technology, and I am under obligation to Pro-

fessor Charles R. Cross and two of his assistants, Mr. C. L. Norton and Mr. R. R. Lawrence, for their coöperation. I also desire to express my appreciation of the active interest taken by the trustees of the Boston City Hospital in my work, and the kindness of my colleagues on the staff for affording me an opportunity of examining many of their patients.

SUMMARY.

Apparatus and methods described.

Respective uses of fluorescope and radiograph considered.

Causes of the difference in permeability which the tissues and organs of the body offer to the passage of the X-rays.

Calculi and instrument for radiographing them in the bladder.

Normal thorax described as seen in the fluorescope.

Importance of the position and movement of the diaphragm in estimating or excluding abnormal conditions of the lungs.

Uses of fluorescope in tuberculosis, pneumonia, pleurisy, aneurism, emphysema and oedema of the lungs considered and illustrative cases given:

The fluorescope gives us earlier evidence of disease in some cases of tuberculosis, and in pneumonia more accurate information, than can be obtained by the usual physical examination.

The fluorescope gives us the means of making an earlier diagnosis of certain cases of thoracic aneurism than any other method.

The fluorescope enables us to recognize or exclude emphysema.

The fluorescope assists us to recognize oedema of the lungs, pneumo-thorax and hydro-thorax.

The fluorescope shows a displacement of the heart in pleurisy, which is sometimes not recognized by other means.

The fluorescope assists in the recognition of fluid in the pleural cavity.

The fluorescope enables us to outline the heart more accurately and more completely than has hitherto been possible, and assists us to recognize certain changes in the heart.

Examples of surgical uses.